

1.3 μm Quantum-Dot Lasers with Improved High Temperature Properties

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The growth of selforganized InAs quantum dots allows the realization of lasers emitting at 1,3 μm on GaAs substrates. Beside the principal advantage that GaAs substrates can be used instead of InP substrates for large volume production quantum dot related effects like very low transparency current densities and low internal absorption are also of importance. Other predictions of quantum dot lasers like low temperature dependence could not be realized up to now for room temperature and above. Especially in the case of 1.3 μm emitting quantum dot lasers good high temperature performance is still a problem.

We have realized 1,3 μm emitting graded index separate confinement heterostructure lasers with InAs dots embedded in a 10 nm thick $\text{Ga}_{0.85}\text{In}_{0.15}\text{As}$ quantum well. Our structure additionally uses short period superlattices (SSLs) in the graded regions to improve the carrier confinement by electron back reflection [1, 2]. This improvement allow ground state lasing at temperatures $> 80^\circ\text{C}$. Multi quantum dot structures with large dot layer separation of 50 nm were used to avoid any strain coupling and to minimize strain accumulation. The growth temperature for the quantum dot layers was 510°C and for the 1.6 μm thick cladding layers 570°C , respectively.

The influence of the amount of quantum dots on the laser performance was investigated by varying the number of dot layers from 3 to 8 layers. The best results were obtained with 6 uncoupled quantum dot layers with transparency current densities of less than 40 A/cm^2 (c.f. Fig. 1), an internal quantum efficiency of about 35% and an internal absorption of $1\text{--}2\text{ cm}^{-1}$. Ridge waveguide lasers with 4 μm ridge width and cavity lengths as short as 800 μm long can be operated at room temperature in cw mode without any facet coatings. These devices show good temperature characteristics with $T_0 > 70\text{ K}$ up to about 50°C and 54 K up to 140°C , respectively (c.f. Fig. 2). The maximum operation temperature was above 150°C which is the highest value known up to now for 1.3 μm emitting quantum dot lasers.

Due to the improved gain by 6 dot layers with an average dot density per layer of about $1 \times 10^{11}\text{ cm}^{-2}$ and the low internal absorption high performance short cavity devices could be realized using high reflection facet coatings (83% for front and 95% for backside facets, respectively). 400 μm long devices exhibit threshold currents as low as 6 mA and more than 5 mW output power at 30 mA (c.f. Fig. 3). Emission from the fundamental dot states was achieved from cw operating unmounted devices up to 70°C ($\lambda = 1.29\text{ }\mu\text{m}$) with more than 2 mW output power. The maximum cw operation temperature was 90°C . More details in the temperature behavior will be presented at the conference.

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- [1] F. Schäfer, B. Mayer, J.P. Reithmaier, A. Forchel, Appl. Phys. Lett. **73**, 2863 (1998).
 - [2] F. Schäfer, J.P. Reithmaier, A. Forchel, Appl. Phys. Lett. **74**, 2915 (1999).

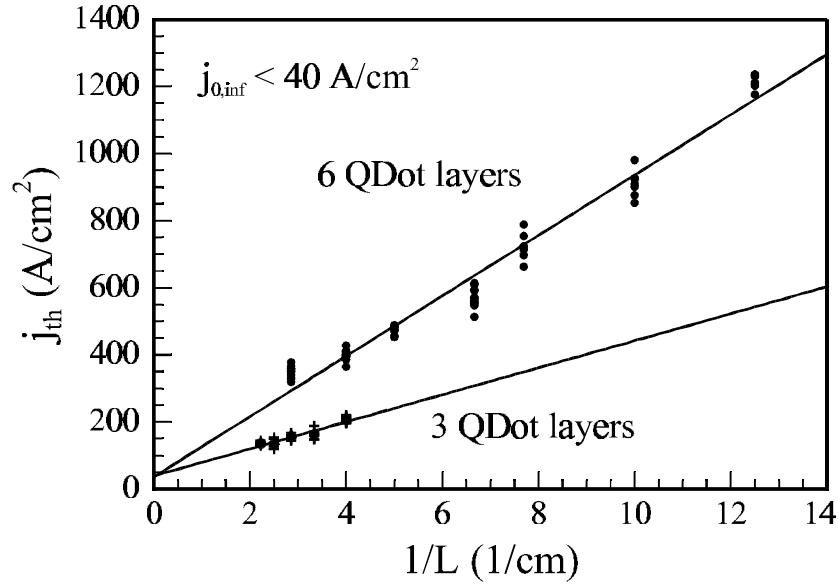


Fig. 1: Threshold current density of 2 samples with different numbers of quantum dot layers as function of the inverse cavity length. Values determined in pulsed operation for 100 μ m wide broad area lasers at 20 °C.

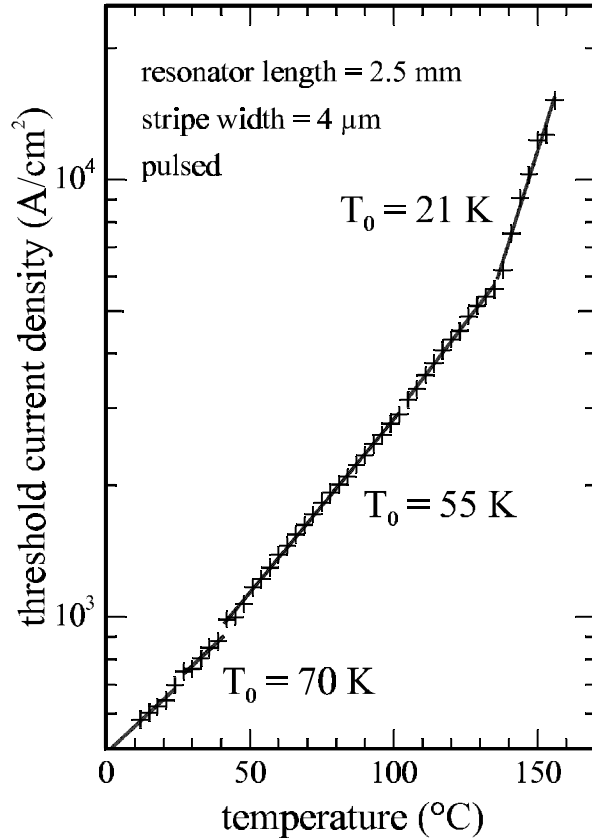


Fig. 2: Temperature dependence of the threshold current density of a 2.5 mm long uncoated ridge waveguide laser with 6 quantum dot layers.

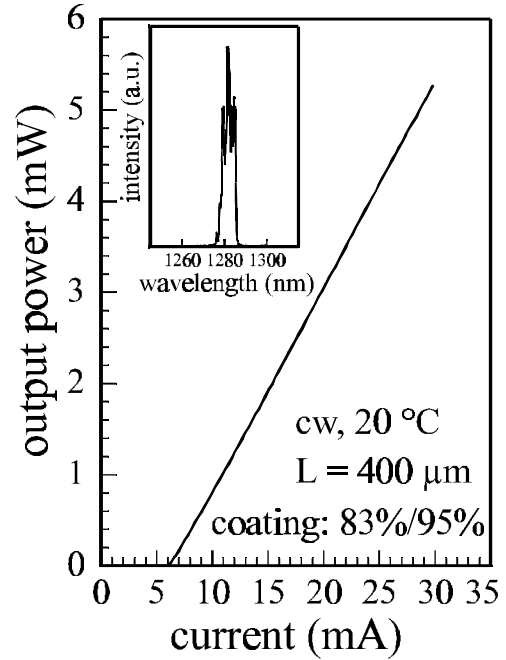


Fig. 3: Light output characteristic of a 400 μ m long HR/HR coated ridge waveguide laser with 6 quantum dot layers. The inset shows the spectrum at 20 mA injection current.